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A METHOD OF EXCITING RESONANT VIBRATIONS IN MECHANICAL SYSTEMS

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ABSTRACT

This brief note describes the essential features of a method of exciting resonant vibrations in mechanical systems, developed for the study of the vibrations of aircraft propellers.

In the study of the vibrations of aircraft propellers, a method of exciting resonant vibrations has been devised which may find application to other mechanical systems. We are therefore publishing this brief description.

It was desired to study the vibrations which might be caused by the periodic variations in torque of an aircraft engine due to the explosions in the individual cylinders, or by the passage of the blades past struts or other asymmetric parts of the airplane structure. Because of the inertial and aerodynamic coupling between the rotational motion of the shaft and the flexural motion of the propeller blade, strong vibrations of the propeller blade may be set up if the period of the torque impulses coincides with a natural frequency of vibration of the blade. The stresses set up by such resonant vibrations may be sufficient to cause failure of the propeller.

As the first stage in the study of these vibrations, attention has been confined to nonrotating propellers. It is of course possible to apply periodic inpulses by means of a mechanically driven system employing either a group of rotating unbalanced weights or a direct drive from a crank and connecting rod. We were, however, early attracted to an electromagnetic drive because of the ease with which the frequency and magnitude of the variation of torque could be independently controlled. The primary electrical equipment required is an alternator driven by a variable speed d.c. motor, the frequency being adjusted by adjusting the speed of the driving motor and the magnitude of the impulses being regulated by the excitation of the field of the alternator.

When the design of the electromagnetic drive was under consideration, it occurred to one of us that there was already existent an efficient device for the utilization of electric current to produce mechanical torque, namely, an ordinary direct-current motor. To produce alternating torque instead of a steady torque it is only necessary to supply alternating current to the armature instead of direct current, the field being supplied with direct current in the usual manner. Unless large angular motions are to be utilized (possible only at very low frequencies because of the inertia of the armature), no modification

in the direct-current motor is required. If large motions are to be permitted, flexible leads or slip rings may be attached to two bars of the commutator at a spacing equal to the spacing of the field poles.

We have set up such a system, using a 7½ horsepower d.c. motor. With this comparatively small motor and an alternator and driving motor which were available we have been able to produce resonant vibrations of sufficient intensity to break ordinary propeller blades in from 5 to 10 hours. The breaks were typical fatigue breaks.

At present the equipment is being used to study the stress distribution in the vibrating propellers. Tuckerman optical strain gages are mounted on the blade, and the relations between the strain amplitude and tip amplitude of the vibration are determined for different amplitudes and frequencies and different positions along the blades.

It is found that for any given position and frequency the strain amplitude is proportional to the tip amplitude. With frequencies varied from 20 percent below up to 10 percent above the lowest resonant frequency, the strain distribution along the blade for a given tip amplitude is not greatly changed.

The apparatus is now being modified to study the strain distribution at higher resonant frequencies.

With this equipment it is also possible to determine the tip amplitude of vibrations produced by a known variation of torque and hence the stress distribution throughout the blade for a known torque variation. The stresses due to vibration may be combined with the direct bending and centrifugal stresses computed in the usual manner and if the strength of the material under combined alternating and direct stress is known, the factor of safety of the design may be determined.

It is quite possible to extend the system to rotating propellers, using, of course, a much larger d.c. motor supplied with d.c. current to rotate the propeller at its rated speed, the alternating current being introduced through a transformer. The measurement of strain distribution in rotating propellers is, however, still an unsolved problem.

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